

of this year. There was more than the usual variation in the amount of clear weather in different parts of the district. At Eastport, Me., and Hartford, Conn., the percentages of possible sunshine were, respectively, 40 and 45, while at Baltimore, Md., and Mount Weather, Va., the percentages were 74 and 76. The average number of days with 80 per cent or more of possible sunshine was 14, and with 20 per cent or less, 7.

#### EFFECTS OF THE ERECTION OF NEW AND HIGH BUILDINGS ON THE RECORDS OF WIND VELOCITY AND DIRECTION AT THE NEW YORK WEATHER BUREAU OFFICE.

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On October 16, 1898, the wind-recording instruments of the U. S. Weather Bureau station in New York City were moved from the Manhattan Life Building to the American Surety Building, which is situated on the southeast corner of Broadway and Pine streets, one-half mile from the southern end of Manhattan Island and about 1,100 feet east of the Hudson, or North River. Fig. 1 shows the details regarding the location of that and other buildings in the vicinity. With the exception of Trinity Churchyard the entire district shown is, and was at the time of the removal, compactly built up, many of the structures being "skyscrapers." On May 14, 1900, the anemometer and windvane,<sup>1</sup> which up to this time had been exposed on special supports placed on the roof, were moved to the summit of a steel tower near the southwest corner of the roof, where they have since remained. The anemometer is 45 feet above the roof, 350 feet above the street, or 387 feet above sea level, which is practically the level of the Hudson River.

For a few years at the beginning of the record on the American Surety Building (which is 21 stories in height, only about 85 feet square, and built on one of the highest plots in the vicinity), this structure towered above others in its immediate vicinity, the air currents had free sweep, and high velocities were recorded. The prevailing winds (northwest and west) were least retarded as they came freely from the Hudson River, which is a mile wide at that point; other winds were more retarded by buildings, the tallest of which were most numerous to the southward. Beginning in the summer of 1902 with the erection of the Hanover Bank Building only 105 feet distant to the east-southeast, there have been put up a number of "skyscrapers" that might reasonably be expected to modify the wind record; nearly all of the important ones, from our point of view, were completed before 1908. Fig. 1 shows the locations of these buildings and several others of special interest; while Table 1 gives the height of these buildings above the street, and above sea level (close approximations in some cases). Figs. 2 and 3, views from the Hudson River, taken in 1901 and 1908, respectively, give an excellent idea of the changes that have taken place in the surroundings during that period. From Table 1 it will be seen that the Singer Tower, the City Investing Building Tower, and the Liberty Tower are the only structures close at hand that project above the level of the anemometer; and that the Hanover Bank Building, the tower of the Manhattan Life Building, and the Trinity Building Tower (a small affair) are the only others in the vicinity that reach the level of the roof of the American Surety Building. But all the buildings listed, and many others to a less degree must have their effects, direct or indirect, in deflecting the air currents at the anemometer level and retarding them by increasing their turbulence, and especially by producing vertical components of motion. The pattern of instruments used and other conditions at the office building having been constant, any change in the record not

due to actual variation in the velocity of the free air currents must be ascribed to changed surroundings.

TABLE 1.—*Tall buildings erected since the summer of 1902.*

Key to fig. 1.	Building.	Height in feet.	
		Above street.	Above sea level. <sup>1</sup>
1	American Surety..... (Weather Bureau Office. X, Instrument Tower.)	305	342
	NEW BUILDINGS. (Shaded areas on map.)		
2	Hanover Bank.....	329	363
3	Singer Tower.....	612	646
4	City Investing (Main Tower.).....	486	513
5, 6	Hudson Terminal.....	277	303
7	Trinity Building, Main part.....	280	317
	Trinity Building, Tower.....	350	387
8	United States Realty.....	282	319
9	Fidelity and Casualty.....	251	280
10	Commercial Cables.....	317	337
12	60 Wall Street.....	346	368
13	West Street.....	315	320
14	United States Express.....	302	323
15	Liberty Tower.....	401	435
21	Wall Street Exchange.....	318	342
	OLDER BUILDINGS.		
11	Broad Exchange.....	279	294
16	Manhattan Life (New Street side).....	268	292
	Manhattan Tower (above Broadway).....	355	390
17	Empire.....	283	318
18	Gillender (recently demolished).....	243	272
19	National Bank of Commerce.....	270	306
20	Washington Life.....	286	321

<sup>1</sup>Close approximations in some cases.

It is our purpose to investigate the modifications of the record that have taken place since the period of free exposure. Fig. 4 shows, graphically, for each year since 1898, the number of days with winds of 40 miles per hour, or more, at the Weather Bureau stations at New York City, Block Island, R. I., New Haven, Conn., Atlantic City, N. J., and Philadelphia, Pa. Fig. 5 gives, graphically, for each month and year from 1899 to 1909, inclusive, the average hourly wind movement at the above stations and at Central Park, New York City (New York Meteorological Observatory).<sup>2</sup> The elevations at Philadelphia and Central Park remained constant during the period. The sharp drop in the lines for Atlantic City between 1901 and 1902 is coincident with a reduction in elevation at that station. The instruments at New Haven and Block Island have been moved; in the case of the latter they were lowered, but the exposure has been very good during the entire period. Even without allowing for reduced elevation at Block Island, figs. 4 and 5 show a pronounced decrease in the winds at New York with respect to those at the other stations. There is an actual decrease in hourly wind movement from an average of 14.7 miles for 1900, 1901, and 1902 to an average of 12.3 for 1907, 1908, and 1909, a fall of over 16 per cent.

For the purpose of examining this reduction minutely and separating from any true reduction that may have occurred the falling off due to changed exposure, we will compare in detail the New York City Weather Bureau records with those obtained at the New York Meteorological Observatory. The latter institution is maintained by the city of New York under the direction of Dr. Daniel Draper, who has kept a continuous record for over 40 years. The data obtained include hourly wind movement in miles per hour, and direction at each hour to 16 points of the compass. Doctor Draper's instruments are exposed at an elevation of 79 feet above the ground on the roof of the Arsenal in Central Park, about 4½ miles north-northeast of the Weather Bureau office. Immediate surroundings have not changed much since 1898, and the changes that have occurred (growth of trees, progress of building in the vicinity,

<sup>1</sup>Standard Weather Bureau anemometer recording each mile of wind movement and wind vane with attachments for recording each minute the direction to 8 points of the compass. The anemometer in its later position is attached to the axis of the vane, directly above the latter.

<sup>2</sup>For lack of space, curves for January and the year, only, are reproduced; but the others show the same general characteristics.

etc.), if of appreciable effect, tend to counteract, in a comparison, evidences of a reduction in velocity at the down-town station. The method of comparison used in this study does not necessitate a comparison of instruments or a discussion of the exposure at Central Park; it depends upon the constancy of conditions there, and, since there is no evidence of any material change in the exposure of the instruments at the Park during the whole period, we may reasonably conclude that if a given wind at Central Park was accompanied, on the average, by a certain wind at the Weather Bureau station during 1900, 1901, and 1902, similar winds will now usually correspond, unless the exposure at the latter station has been modified.

The first step in our comparison was tabulating together the hourly wind direction and movement at the two stations for each hour during several months in both periods just mentioned. With the exceptions noted below, the directions almost always agree during steady winds, and a relation between velocities is at once apparent. Next the movements at the Weather Bureau corresponding to each velocity recorded at Central Park were arranged in columns, for early and late years separately, and means taken of each column. Then similar tables were made and means computed for each of the 8 cardinal points of the compass; intercardinal points in the Central Park record were assigned to the cardinal point nearest that recorded at the other station at the time. The figures for directions not exactly agreeing after this modification were kept separate and were not used in computing means, except as noted below. In the early record a tendency exists for west winds at the city observatory to become northwest at the Weather Bureau office; in the later record this tendency disappears. In the early record about 30 per cent of Central Park's north winds become northeast and northwest at the Weather Bureau office; later the percentage is more than 80, and the hourly figures were used in obtaining means. (All means are given in Table 2).

Then, with movements at Central Park as abscissæ and movements at the Weather Bureau as ordinates, results were plotted on cross-section paper and smooth curves drawn for each case (see fig. 6). From these curves we can obtain directly the early and late Weather Bureau velocities corresponding on the average to any given Central Park velocity and direction; and, similarly, given the Weather Bureau velocity we can obtain the usual corresponding record at Central Park

Also the decrease in the Weather Bureau record is given in detail for each case by the length of the portions of the ordinates intercepted between the early and late curves.

From fig. 6 it will be seen that:

1. There has been a considerable reduction in wind movement at the Weather Bureau station on account of new buildings erected.

2. North winds have been affected the most; northeast and east have not been changed materially; while other directions have been considerably reduced. Table 3 gives present movements and reductions per cent for original movements of 10 miles and multiples thereof.

3. Very low velocities have been reduced but slightly or not at all; when, for any direction, we find a reduction, it increases with the velocity.

4. For each direction there is a different relation between velocities; due, no doubt, to local conditions at the two stations. In each case the movement at the Weather Bureau Observatory may be expressed as a function of the movement at the other station by finding the equation of the corresponding curve. Thus, for the early record of southeast winds, we have, very closely,

$$y = \frac{(x+5)^3}{240} + \frac{x+5}{2} + 3.5$$

where  $y$  is the movement at the former station and  $x$  the movement at the latter. For northeast winds we have a straight line with the equation,

$$y = 1.4x + 4.1$$

5. If we exclude velocities of 5 miles, or less, at Central Park, the relations may be closely shown by straight lines, and the forms of the corresponding functions are very simple, being shown on the face of fig. 6.

It is plain that the exposure for winds from the north has been much impaired by the massing of tall buildings in that direction; but this is not as serious a matter as might at first appear, these winds being comparatively light and infrequent. Southeast and south winds, although considerably reduced, still give good records; nor have the prevailing westerlies (northwest to southwest) suffered serious deflection, or velocity reduction, and northeast winds, which are frequent, have not been noticeably affected.

TABLE 2.—Average hourly wind movement at Weather Bureau office, corresponding to given hourly wind movement at Central Park.

Wind movement at Central Park (miles per hour).	Direction of wind at Central Park.															
	North.		Northeast.		East.		Southeast.		South.		Southwest.		West.		Northwest.	
	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.	Early record.	Late record.
0	4.5			5.0	5.2	5.5				3.8			5.7	5.6	5.9	4.7
1	7.5		5.6	4.0	7.1	6.7	5.9	(8.5)	7.5	6.6	6.9	7.6	7.6	6.3	6.6	6.3
2	7.6		7.5	8.0	6.1	7.6	8.3	10.8	7.6	7.5	6.1	6.8	6.8	7.8	8.9	9.2
3	8.4	6.6	7.4	9.2	9.4	9.7	9.2	10.8	8.4	8.1	5.9	6.8	8.2	8.2	9.1	10.2
4	11.3	8.4	10.0	10.1	9.1	13.8	11.5	8.4	11.3	8.9	7.5	7.4	9.1	9.8	9.7	9.6
5	12.0	8.7	11.0	10.4	11.5	12.5	14.3	10.6	12.0	10.2	7.8	8.9	9.7	11.0	11.8	11.4
6	12.2	9.6	12.4	11.2	14.1	15.2	14.4	12.4	12.2	12.0	8.4	8.7	12.1	12.0	13.0	11.3
7	15.8	9.5	12.7	13.9	14.4	14.8	15.2	11.6	15.8	12.6	10.5	10.4	14.7	12.8	14.8	13.1
8	16.5	10.0	15.3	13.6	21.8	19.9	17.5	15.2	16.5	11.9	9.8	9.9	14.0	15.2	18.9	14.0
9	15.1	11.0	19.6	16.3		18.1	20.0	15.9	15.1	12.4	10.1	9.8	15.1	15.5	18.6	14.9
10	20.0	11.1	19.3	18.9	27.4	25.5	27.3		20.0	15.3	14.0	12.7	16.8	16.4	20.1	17.2
11	(20.5)	12.3	20.7	19.6		26.2	27.7		(20.5)	15.7	12.7	11.2	22.4	18.5	24.0	18.9
12		12.2	21.6	21.1		27.8	35.2			17.2	14.7	11.6	24.6	19.9	25.0	21.6
13	23.7	11.2	23.9	22.4			39.5		23.7	16.2	15.6	14.9	26.3	21.7	26.9	22.9
14		13.6	24.6	25.1							14.7	14.8		22.0	29.1	25.3
15		13.3	25.8	25.4									32.0	22.2	32.9	26.0
16	(29.0)	16.0	25.3	26.1					(29.0)		20.0	17.0		27.1	31.5	28.3
17		17.1	(29.8)							27.7			34.3	29.7	37.1	31.0
18		21.2											39.8	31.4	39.4	31.9
19		16.8											39.7	29.1	39.3	30.9
20													41.4	34.5	41.4	30.2
21													49.8	39.2	40.2	34.6
22													47.0	38.3	46.2	
23															42.6	32.2
24													46.0	40.4		
25													57.0		54.2	
26													56.7			
27															54.0	

<sup>1</sup>Means include corresponding Northeast and Northwest winds (see text).

TABLE 3.—Reduction in wind movement at the Weather Bureau office.

Directions.	Former movement 10 miles per hour.		Former movement 20 miles per hour.		Former movement 30 miles per hour.		Former movement 40 miles per hour.		Former movement 50 miles per hour.	
	Present movement.	Reduction.	Present movement.	Reduction.	Present movement.	Reduction.	Present movement.	Reduction.	Present movement.	Reduction.
		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>
North.....	7.3	27	11.0	45						
Northeast.....	10.0	0	20.0	0	30.0	0				
East.....	10.0	0	19.0	5						
Southeast.....	9.4	6	15.6	22						
South.....	8.6	14	15.3	23.5						
Southwest.....	9.8	2								
West.....	9.6	4	17.6	12	25.0	16.7	32.7	18.2	40.5	19
Northwest.....	9.0	10	17.0	15	25.2	16	32.6	18.5		
Average of all.....	8.9	11	15.8	21	23.2	22.7	31.2	22	39.3	23.4

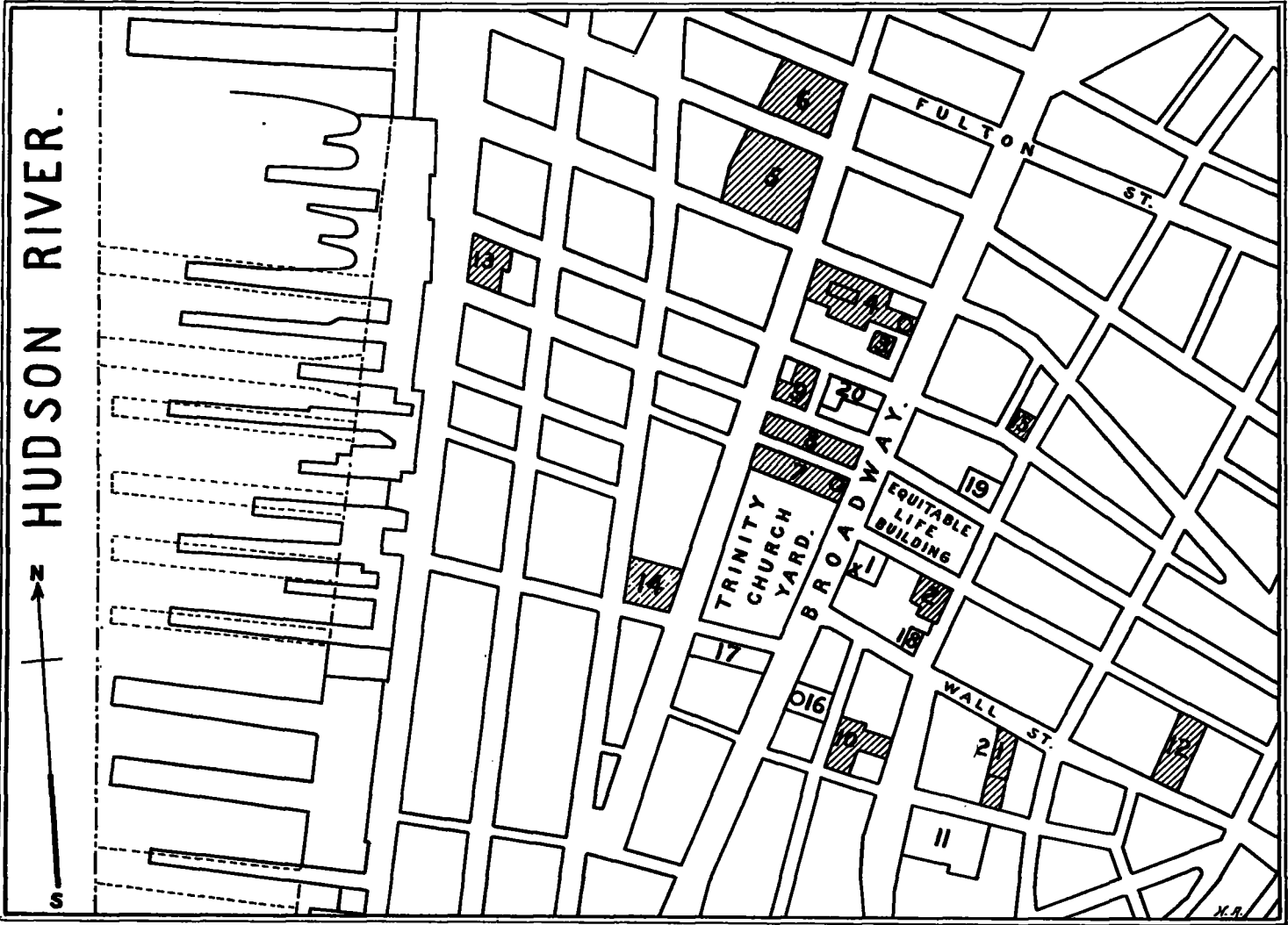


FIG. 1.—Section of southern portion of Manhattan Island, showing location of Weather Bureau office with respect to other buildings in vicinity.



FIG. 2.—Water front, New York, in 1901. Arrow indicates location of U. S. Weather Bureau office.



FIG. 3.—Water front, New York, in 1908. Arrow indicates location of U. S. Weather Bureau office.

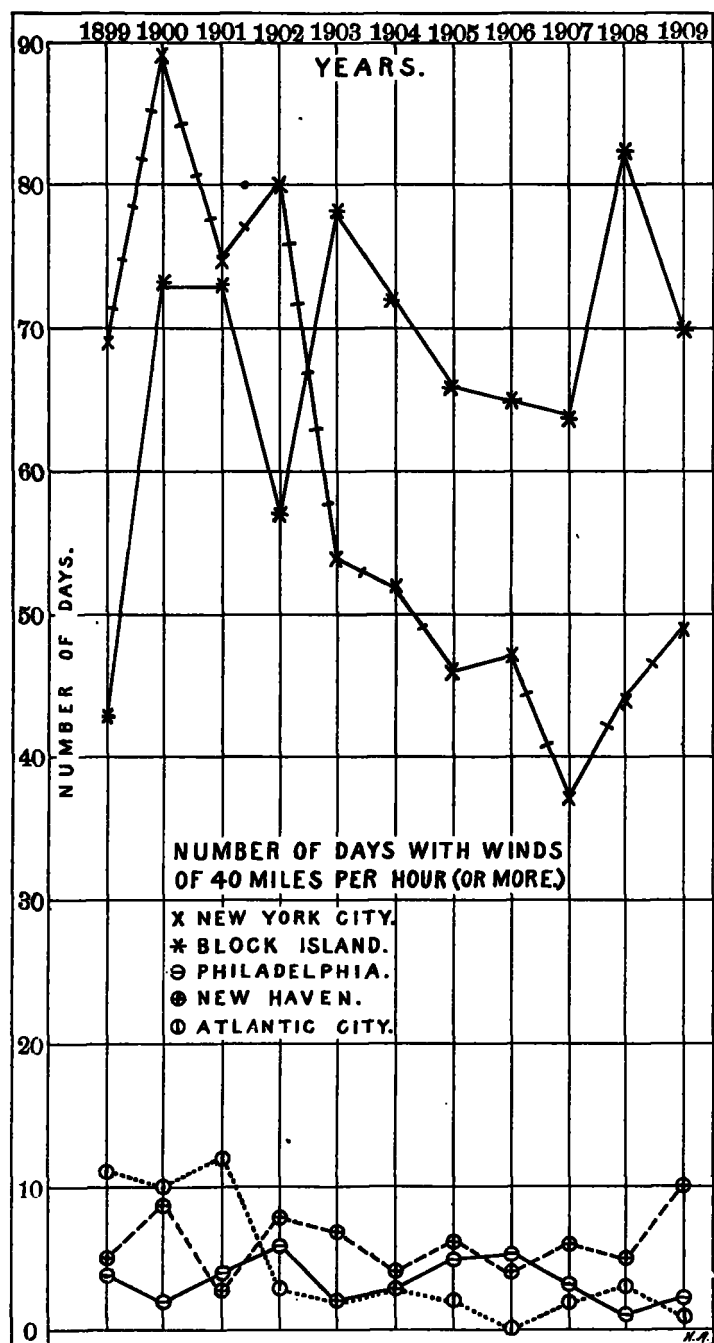


FIG. 4.

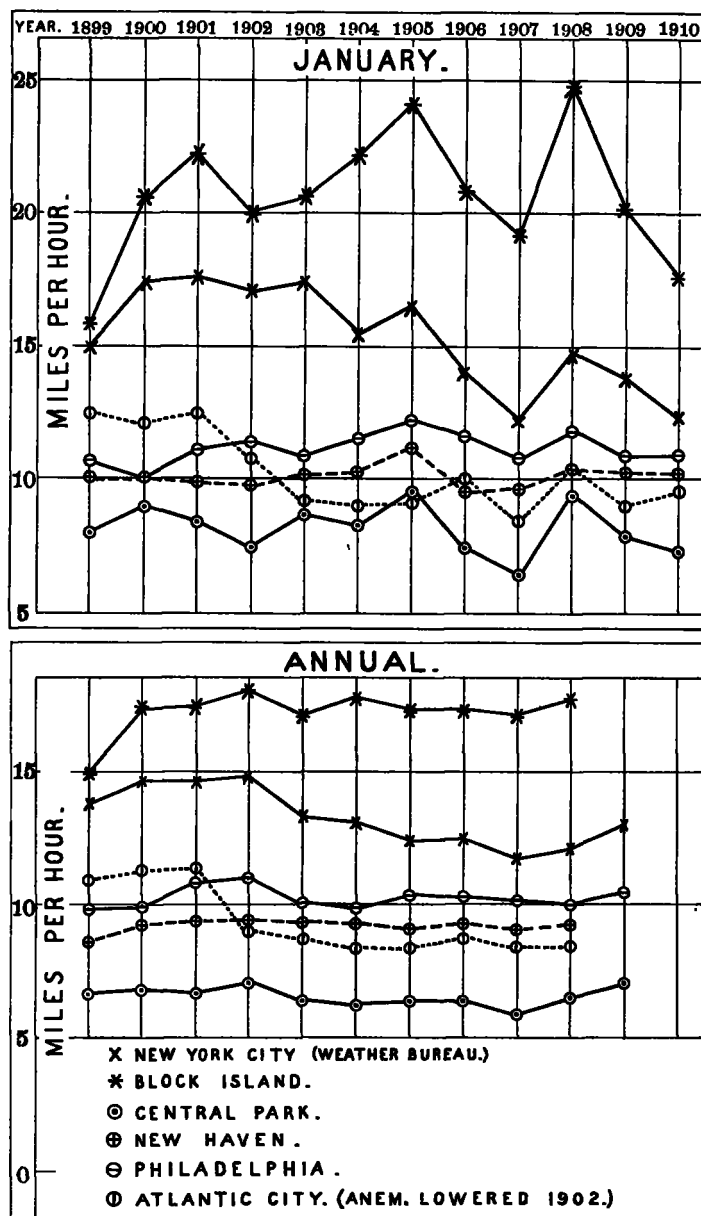


FIG. 5.

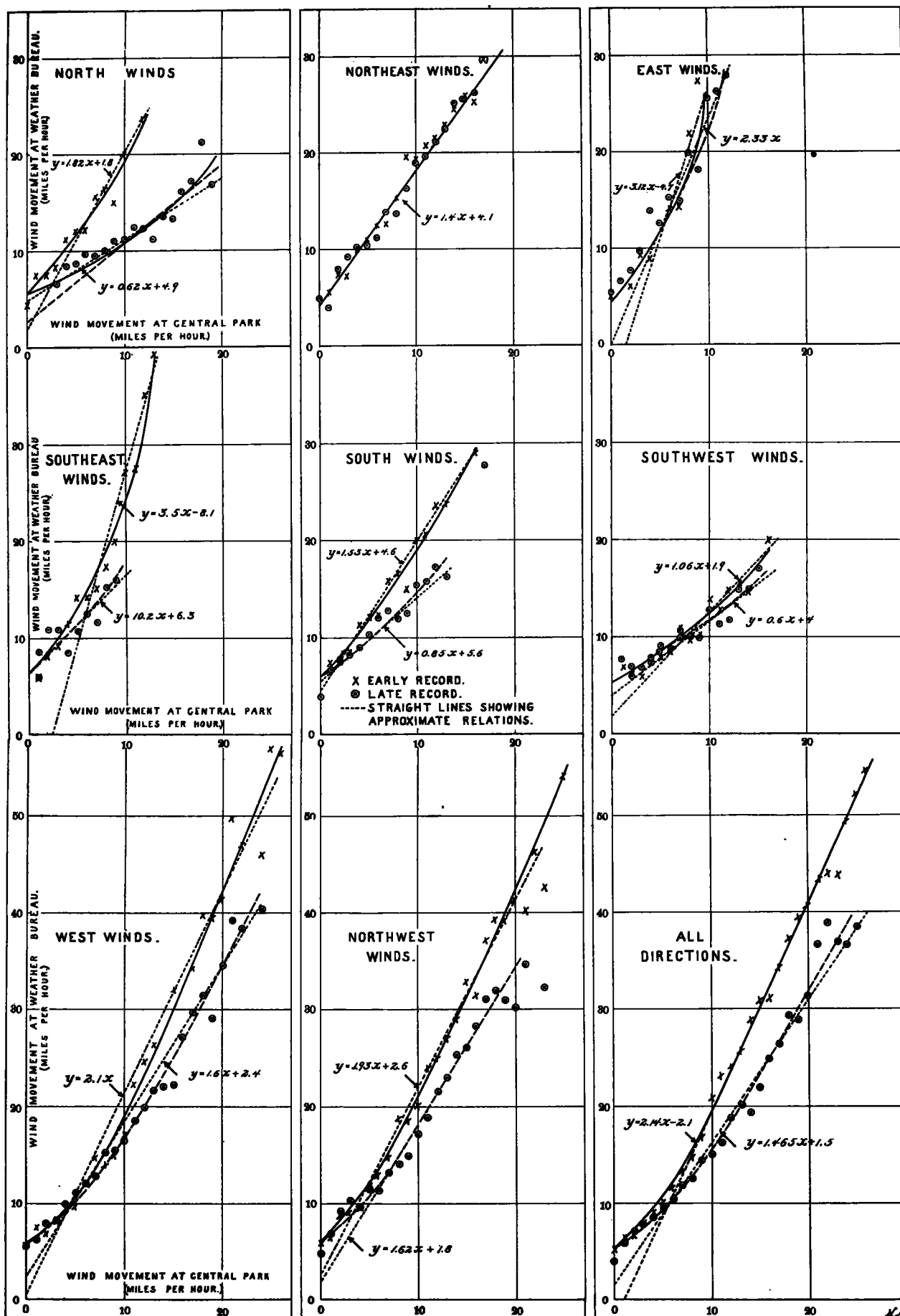


FIG. 6.